

PATENT SPECIFICATION

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(54) METHOD AND APPARATUS FOR INJECTION MOULDING OF EXPANDED PLASTICS ARTICLES

(71) We, GEBRUEDER BUEHLER AG, a Swiss Body Corporate, of CH 9240 Uzwil, Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The invention relates to a method and apparatus for producing moulded articles having an outer skin and a porous or cellular core.

It is known to produce such articles by injection moulding of a melt of plasticised plastics material containing expanding agent into a mould cavity, in which a gas counter-pressure prevails for preventing the expansion of the expanding agent during the mould filling operation, and from which the gas is displaced by the melt as the filling of the mould progresses.

In order to obtain so-called structural foam articles of this kind which have a smooth surface it is known for the plastics material melt mixed with an expanding agent, referred to hereinafter simply as the melt, to be injected against the pressure of a gas previously introduced into the mould cavity at a supply point.

The injection pressure is always greater than the counter-pressure of the gas, which itself is greater than the expansion pressure of the expanding agent to prevent foaming of the melt before the mould filling operation is completed.

Owing to these pressure conditions, with a substantially constant counter-pressure, the gas recedes before the flow front of the melt filling the mould cavity, back through the discharge point which is also the supply point and when the filling of the mould is completed the gas is expected to have been displaced completely from the mould cavity.

However, experience shows that this is true only in the case of injection moulding

moulds for structural foam parts of quite simple geometry and even with these does not always happen. Tests have shown that the flow front of the melt in some cases forms flow shadows or traps from which the gas cannot flow out even in the injection moulding of moulded parts of relatively simple shape.

This kind of behaviour becomes more and more apparent when complicated structural foam parts with several recesses or apertures have to be produced. In such cases the gas often remains trapped by the melt in spaces between the mould cores which are provided to form such recesses. The melt is thus prevented from filling these intermediate spaces resulting in the moulded parts being unusable.

The invention has as one of its objects to provide an improved method for injection moulding of expanded plastics articles.

According to one of its aspects the invention provides a method for the production by injection moulding of plastics articles having an outer skin and a cellular or porous expanded core, including the steps of injecting a plastics material melt containing foaming agent into a mould in which a gas counter pressure prevails to counter expansion of the melt during the mould filling, causing or permitting gas to be progressively displaced by the melt as the mould is filled and additionally causing or permitting pockets of gas to be relieved of pressure that are trapped by the flow front of the flowing melt and to be removed from the mould cavity.

This method makes it possible for a gas cushion which has just been enclosed and which obstructs the melt to be cleared out of the way before the setting flow front solidifies, so that the mould cavity is filled without leaving a gap.

For pressure relief of the gas inclusions and for removing them from the mould cavity, advantageously there can be used the

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- gas-perviousness of capillary action venting passages in conjunction with the inability of the melt to penetrate into such venting passages because of its surface tension.
- 5 Conveniently the pressure relief and clearing away of the gas inclusions are controlled separately from one another in space and time.
- 10 It is preferred to carry out the control separately as regards space and time in accordance with a programme adapted to the mould filling operation.
- 15 Apparatus is known for producing expanded plastics articles with an expanded thermoplastics injection-moulding machine having a split injection moulding mould whose mould cavity in the closed state is adapted to be pressure loaded by means of a gas and to be cleared gradually of the gas charge during the mould filling operation by means of a duct constructed in the injection moulding mould and a charging/discharging valve preceding that duct.
- 20 Several proposals are known for an apparatus for carrying a gas counter-pressure method with displacement of gas from the mould cavity by the melt. They all relate to injection moulding moulds for structural foam parts of simple geometric construction and accordingly all propose the use of a discharge valve which simply allows the gas to flow out from the entire mould cavity.
- 25 To produce complicated structural foam parts with a smooth surface, on the other hand, apparatus is known which uses either the method of mould cavity volume variation or the so-called two-phase gas counter-pressure method.
- 30 As is known, in the first case the volume of the mould cavity can be reduced by means of a plunger arranged for displacement in the injection moulding mould in order thereby to prevent the foaming of the melt during the mould filling operation.
- 35 Additionally a gas counter-pressure can also be used, gas being introduced into the mould cavity by way of a charging/discharging valve before the beginning of the mould filling operation and discharged from the cavity during the mould filling operation.
- 40 In the second case the gas counter-pressure built up previously in the mould cavity by way of a charging valve is increased during a first phase of the mould filling operation possibly with the use of a second charging valve, and the higher pressure is kept constant in a subsequent second phase until the mould filling operation is completed, the gas flowing out through a discharge valve.
- 45 The invention has as another of its objects to provide an improved injection moulding apparatus for moulding expanded plastics articles.
- 50 According to another of its aspects the invention provides an apparatus for the production by injection moulding of plastics articles having an outer skin and a cellular or porous expanded core, including a mould, means for injecting a plastics material melt containing foaming agent into the mould, means for causing a gas counter pressure to prevail in the mould to counter expansion of the gas during mould filling, means for causing or permitting gas to be progressively displaced by the melt as the mould is filled, and additional relief means for additionally causing or permitting pockets of gas to be relieved of pressure that are trapped by the flow front of the flowing melt and to be removed from the mould cavity. Preferably the additional relief means comprises at least one capillary action gas pervious passage in a wall of the mould adapted to be vented by way of a pressure relief chamber and a shut off valve leading from that chamber to atmosphere.
- 55 The capillary-action gas-pervious arrangements at the places where there is a danger of gas inclusions, controlled by means of the relief chambers by the shutoff valves, allow for the gas inclusions to be immediately broken down at the technologically necessary instant of time in accordance with the degree to which the mould has been filled during the mould filling operation.
- 60 Undesired passage of the still liquid melt through the arrangement, which would thus block the arrangement and produce surface defects on the moulded article, for example the formation of flash, can be obviated.
- 65 For example in a first constructional form of the apparatus utilising the invention, in which the injection moulding mould is to have several mould cores corresponding to a number of recesses to be provided in the moulded part, it is possible to arrange the mould cores securely each in a recess of a mould half of the injection moulding mould. It is preferred to provide in the region of the recess adjacent the mould cavity between the wall thereof and the mould core a gas-pervious gap through which the melt cannot penetrate, to provide a chamber adjacent the gap in that region of the recess between the wall thereof and the mould core which is remote from the mould cavity, and to arrange after the chamber a venting duct which leads to the shutoff valve and which has a cross-section corresponding to the throughflow ability of the chamber.
- 70 By the secure arrangement of the mould cores in the recesses it is possible to prevent escape of the gas counter-pressure from the mould cavity earlier than is technologically necessary.
- 75 The passage of the melt between the mould core and the wall of the recess can be
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- prevented by selecting a gap width into which the melt does not penetrate because of its surface tension determined by its viscosity.
- 5 Conveniently a gap of a few hundredths of a millimetre is provided, preferably a gap of 0.02 to 0.04 mm.
- By constructing the chamber following the gap and the venting duct connected thereto with the same throughflow capacity, it is intended to allow a rapid discharge of gas inclusions without anything to hold back the flow.
- To form the chamber, the mould cores can be arranged in the region of the recesses remote from the mould group, set back from the wall of the said recesses.
- In a convenient arrangement the recesses for the moulding cores together with the venting ducts are constructed in the mobile half of the injection moulding mould.
- It is particularly advantageous if the relief chambers each have a remote-controlled shutoff valve associated with them, and the remote control connections of all the shutoff valves are connected to a programmable arrangement for controlling the injection operation.
- In a second constructional form of apparatus utilising the invention, a gas-pervious gap is provided in each case between the ejector pins and the wall of the holes receiving these pins in the end region of these holes opening into the mould cavity, and in the connection to the gap an annularly widened chamber is formed, each of the chambers again being in control connection with the associated shutoff valve by way of a venting duct in each case.
- 40 Two constructional forms of the invention will now be described by way of example with reference to the accompanying drawings, in which:-
- Figure 1 shows a section taken on the plane A-A of Figure 2 through an injection moulding mould for the production of structural foam parts having a plurality of recesses and a smooth surface in a gas counter-pressure method, the injection moulding mould being provided with arrangements for venting gas inclusions.
- Figure 2 shows the mobile half of the injection moulding mould of Figure 1 after the opening thereof, in plan view from the direction of the fixed mould half, and
- Figure 3 shows a modified constructional form in section, provided in an otherwise similar injection moulding mould.
- Figure 1 shows in cross-section an injection moulding mould 1 into which a gas counter-pressure can be admitted. It is used in an expanded thermoplastics injection moulding machine of known construction, referred to in short hereinafter as an ETI machine, whose other parts, which are not necessary for the understanding of the invention, have been omitted for ease of understanding of the drawing.
- The injection moulding mould 1 has a stationary mould half 11 and a mobile mould half 12. In the closed state of the mould in which the two halves contact one another in a mould separating plane 13, the two mould halves 11, 12 enclose a mould cavity 14.
- 70 In the middle of the stationary mould half 11 there is a sprue block 111 with a sprue duct 112 and following this a spherical cavity 113 for an injection nozzle of an injection unit (not shown) of the ETI machine.
- 75 In the lower region of the stationary mould half 11 in Figure 1 a duct 114 is formed for introducing and discharging a gas under pressure into and from the mould cavity 14. At its end nearest the mould separating plane 13, the duct 114 merges into a funnel-shape widening 115 whilst at its end opening on to the base surface of the stationary mould half 11 it has a screw threaded pressure tight connecting sleeve 116.
- 80 The stationary mould half 11, at its surface in the mould separating plane 13, also has a sealing groove 117 which extends in the vicinity of the periphery and which receives a sealing ring 118.
- 85 The funnel-like widening 115 of the gas supply duct is situated opposite a distributing chamber 121 which is provided in the mobile mould half 12 and opens into the mould cavity 14. The distributing chamber 121 extends in the shape of a U at right angles to the plane of the drawing of Figure 1 (see also Figure 2), with a relatively small depth into the mould separating plane 13.
- 90 A distributing groove 122 in the mobile mould half 12 encircles the mould cavity 14 in its surface that lies in the mould separating plane 13 and is connected at both sides to the distributing chamber 121 and to the four corners of the mould cavity 14 (see Figure 2). Three recesses 123 are also shown in the mobile mould half 12 above the level of the sprue duct 112, and below these two further recesses 123. In each of these there is inserted a mould core 124 which is secured by means of a screw bolt 125.
- 100 The sections of the mould cores 124 which project into the mould cavity 14 define intermediate spaces 126 in the said cavity.
- 105 Except for the central recess of the upper three recesses 123, a capillary-action gas-pervious gap 127 is provided in the region of the other recesses 123 adjacent the mould cavity 14 in each case between the recess wall directed towards the intermediate space 126 and the mould core 124. The mould cores 124 in the region of these recesses 123 remote from the mould cavity 14 are stepped back on all sides relatively to
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- the recess wall thus forming chambers 128 which in each case communicate by way of the associated gap 127 with the appropriate intermediate space 126.
- 5 The chambers 128 in the two outer recesses of the upper three recesses 123, which in fact communicate each with a relatively small intermediate space 126 between the central mould core 124 devoid of 10 gap and one of the two outer mould cores 124, are connected by way of respective venting ducts 129 with respective connecting sleeves 130 opening on to the surface of the mobile mould half 12. In Figure 1 only one 15 venting duct 129 is visible, namely the venting duct which leads upwards.
- Associated with the chambers 128 in the two recesses 123 which are formed below the level of the sprue duct and which are 20 connected by way of the associated two ducts 127 to a relatively large intermediate space 126, is a common venting duct 129 which interconnects these chambers 128 and which also leads to a connecting sleeve 130 at an outer surface of the mobile mould half 12.
- 25 A pressure gas bottle 2 can be connected to the mould cavity 14 by way of a conduit 21 connected to the connecting sleeve 116 of the gas supply duct 114 by means of a charging/discharging valve 22 arranged in that conduit.
- It is also possible to provide between the 30 charging/discharging valve 22 and the connecting sleeve 116 of the duct 114 a separate discharging valve 23 whose outlet leads to atmosphere.
- 35 A 2/2-way shutoff valve 3 with a remote control connection 31 for electrical operation is connected by way of in each case a connection 32 to the two venting ducts 129 which are shown in Figure 1 and which start from the chambers 128 of the uppermost and the two lowest recesses 123 respectively.
- 40 The shutoff valve which controls the venting duct 129 (see Figure 2) starting from the chamber 128 of the lowest of the upper three recesses 123 at right angles to the plane of the drawing in Figure 1, is not 45 visible in Figure 1.
- The remote control connections 31 of the shutoff valves 3 are connected by means of an electrical line 33 in each case to a programmable arrangement for controlling the injection unit (not shown) of the ETI machine. The outlets of the shutoff valve 3 50 communicate with atmosphere.
- In Figure 2 contours in full lines show the 55 position of the recesses 123 with the mould cores 124 arranged therein and the gaps 127 provided therebetween in the mobile mould half 12, and also the form of the distributing groove 122 encircling the mould cavity 14 together with the connected distributing chamber 121 in front view.
- By means of contours shown in broken lines there are also indicated the chambers 128 constituted in the recesses 123 by stepping-down the mould cores 124, the venting ducts 129 connected thereto along with their connecting sleeves 130, the screw bolts 125 for securing the mould cores 124 and the mouth of the sprue duct 112 which is situated in the mould separating plane 13.
- 70 A second constructional form of the invention shown in Figure 3 can be used in an injection moulding mould 1 as shown in Figure 1.
- The two mould cores 124 are arranged in stationary manner without a gap in the recesses 123 of the mobile mould half 12 in Figure 3 similarly to the central of the upper three mould cores 124 in Figure 1.
- 75 At the side of the stationary mould half 11 opposite the mould cavity 14 there is associated with the said mould half an ejector plate 4 which can be displaced in and opposite to the direction of injection. In the ejector plate 4, ejector pins 41 are secured in known manner each by means of a flange 42 these being held securely by a cover plate 43 screwed to the ejector plate 4 at the surface of the said plate remote from the stationary mould half 11. In Figure 3 only the ejector pin 41 situated in the drawing plane of this illustration is visible.
- 80 The ejector pins 41 each extend through an ejector hole 44 in the stationary mould half 11, the free end thereof being shown in the retracted position of the ejector plate 4 in the mould separating plane 13.
- 85 In Figure 3 only the ejector hole 44 shown in section through the drawing plane is visible.
- 90 For the ejecting and returning movement of the ejector plate 4 any suitable known mechanical, hydraulic or other driving means can be provided and is not represented here. The ejector plate is guided by means of a plurality of guide pins 45 which slide in suitable holes 46 of the stationary mould half 11. In Figure 3 only one guide pin 45 is shown with outlines partly indicated by broken lines.
- 95 In Figure 3 only the ejector hole 44 shown in section through the drawing plane is visible.
- 100 For the ejecting and returning movement of the ejector plate 4 any suitable known mechanical, hydraulic or other driving means can be provided and is not represented here. The ejector plate is guided by means of a plurality of guide pins 45 which slide in suitable holes 46 of the stationary mould half 11. In Figure 3 only one guide pin 45 is shown with outlines partly indicated by broken lines.
- 105 In the end region of the ejector holes 44 which opens into the mould cavity 14 there is in each case a capillary action gas-pervious gap 48 surrounding the ejector pin 41 in an annular fashion and, connected therewith, a chamber 49 which is also widened in annular fashion.
- 110 Each widened chamber 49 is again connected by way of a venting duct 50 and a connecting sleeve 51 to a connection 32 as
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- was shown in Figure 1 and thence in each case to a 2/2-way shutoff valve 3 whose outlet is taken out to atmosphere as was also shown in Figure 1.
- 5 In the region of the ejector hole 44 which extends from the annularly widened chamber 49 in the direction of the ejector plate 4, there is provided in each case a sealing groove 52 which receives a sealing ring 53.
- 10 The ejector plate 4 could be arranged in known manner together with the ejector pins 41 instead at the mobile mould half 12, and of course there would then also be provided in the mobile mould half 12 the arrangement for pressure relief and venting of a gas cushion entrapped in the intermediate space 126, comprising the gap 48, annularly widened chamber 49 and venting duct 50 with connecting sleeve 51.
- 15 The two constructional forms of the invention which are shown in Figure 1 to Figure 3 allow operation by the method which will now be described.
- 20 When the melt which has flowed in under the injection pressure through the sprue duct 112 spreads out in the mould cavity 14 a flow front is formed which progresses in an arcuate formation substantially in all directions.
- 25 As can easily be seen from Figure 2, during the simultaneous spreading-out of the material both in an upward and in a downward direction the flow front on reaching the first mold core 124 in the particular direction of flow in question adapts itself to the shape of the surface of the said core at the gate side and then flows about the two end surfaces thereof, closing approximately simultaneously the two ends 30 of the intermediate space 126 of the first and second mould cores 124 considered in the direction of flow.
- 35 At this instant, the shutoff valve 3 which up to that point had been closed is opened by its remote control connections 31 in response to a signal of the programmable arrangement for controlling the injection unit. Hence the shutoff valve 3 vents the intermediate space 126 which has just been 40 enclosed, namely in each case by way of a venting duct 129 or 50 and at least one chamber 128 or 49 and a gap 127 or 48 respectively.
- 45 There occurs an immediate pressure relief 50 of the gas cushion which is trapped in this intermediate space 126 and would prevent this space from being filled by the melt, the gas cushion being then displaced to atmosphere by way of the open shutoff valve 3 by 55 the melt entering the intermediate space 126 rapidly, before the slowing down flow front solidified.
- 60 The operation described is repeated at each intermediate space 126 which is successively reached and surrounded by the flow front subsequently in the course of the mould filling process.
- 65 In this way it is possible to ensure that all the portions of the mould cavity which hitherto have been inaccessible because of gas inclusions remaining enclosed can be filled without leaving any gaps, and at the same time these have the desired smooth surface.
- 70 WHAT WE CLAIM IS:-
1. Method for the production by injection moulding of plastics articles having an outer skin and a cellular or porous expanded core, including the steps of injecting a plastics material melt containing foaming agent into a mould in which a gas counter pressure prevails to counter expansion of the melt during the mould filling, causing or permitting gas to be progressively displaced by the melt as the mould is filled and additionally causing or permitting pockets of gas to be relieved of pressure that are trapped by the flow front of the flowing melt and to be removed from the mould cavity. 75
 2. Method according to claim 1 wherein the pressure relief and removal of the entrapped pockets of gas from the mould cavity is by use of gas perviousness of capillary action venting passages in conjunction with the surface tension of the melt bridging these. 80
 3. Method according to claim 1 or claim 2 wherein the pressure relief and removal of gas from separate pockets is controlled separately at different locations and at different points in time. 85
 4. Method according to claim 3 wherein the separate control is carried out immediately after entrapment in accordance with a programme determined in accordance with the mould filling operation. 90
 5. Method for the production by injection moulding of plastics articles having an outer skin and a cellular or porous expanded core, substantially as hereinbefore described with reference to the accompanying drawings. 95
 6. Apparatus for the production by injection moulding of plastics articles having an outer skin and a cellular or porous expanded core, including a mould, means for injecting a plastics material melt containing foaming agent into the mould, means for causing a gas counter pressure to prevail in the mould to counter expansion of the gas during mould filling, means for causing or permitting gas to be progressively displaced by the melt as the mould is filled, and additional relief means for additionally causing or permitting pockets of gas to be relieved of pressure that are trapped by the flow front of the flowing melt and to be removed from the mould cavity. 100
 7. Apparatus according to claim 6 wherein the additional relief means com- 105

- prises at least one capillary action gas pervious passage in a wall of the mould adapted to be vented by way of a pressure relief chamber and a shut off valve leading from that chamber to atmosphere.
8. Apparatus according to claim 7 wherein the mould has a plurality of mould cores for a corresponding plurality of recesses to be formed in articles to be moulded by the apparatus, each mould core being fixed in a mould recess of a mould part of the mould, so as to form in the region of the mould recess adjacent the mould cavity a gas pervious gap between the mould core and the wall of the recess, the gap being of such width that in use of the apparatus the melt does not penetrate such gap.
9. Apparatus according to claim 8 wherein in the region of the mould recess which is remote from the mould cavity a chamber is formed between the mould core and the wall of the recess, the chamber being connected with the gap and with a venting duct which has a cross section of like throughflow capacity as the chamber and which leads to the shutoff valve.
10. Apparatus according to claim 9 wherein the mould core in the region of the recess remote from the mould cavity is stepped back from the wall of the recess to form the chamber.
11. Apparatus according to any of claims 8 to 10 wherein the mould recesses and venting ducts are formed in a movable mould part of the mould.
12. Apparatus according to any one of claims 6 to 11 wherein each additional relief means is vented by way of a remote controlled shut off valve, the remote control connections of respective shut off valves being all operatively connected to a programming device that controls the injection operation.
13. Apparatus according to claim 12 wherein the programming device is adapted to be programmed to cause opening of the shut off valves at points in time that can be selected by reference to the progress of the injection operation.
14. Apparatus according to claim 6 or claim 7 wherein ejector holes extend to the mould cavity, a gas pervious gap is formed in the end region of at least one such hole between the wall of the hole and an ejector pin, said gap opening into a chamber which widens in annular fashion, said chamber being in controlled communication by way of venting duct with an associated shut off valve.
15. Apparatus according to any of claims 7 to 14 wherein the gas pervious passage or gap is of a width of 0.02 to 0.04 mm.
16. Apparatus for the production by injection moulding of plastics articles having

an outer skin and a cellular or porous expanded core, constructed, arranged and adapted for use and operation substantially as shown in and hereinbefore described with reference to Figures 1 and 2 or Figure 3 of the accompanying drawings.

17. An article moulded from plastics material whenever made by the method or apparatus claimed in any preceding claim.

MEWBURN ELLIS & CO.,
Chartered Patent Agents,
70/72 Chancery Lane,
London WC2A 1AD.
Agents for the Applicants.

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COMPLETE SPECIFICATION

3 SHEETS

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the Original on a reduced scale
Sheet 1

Fig. 1

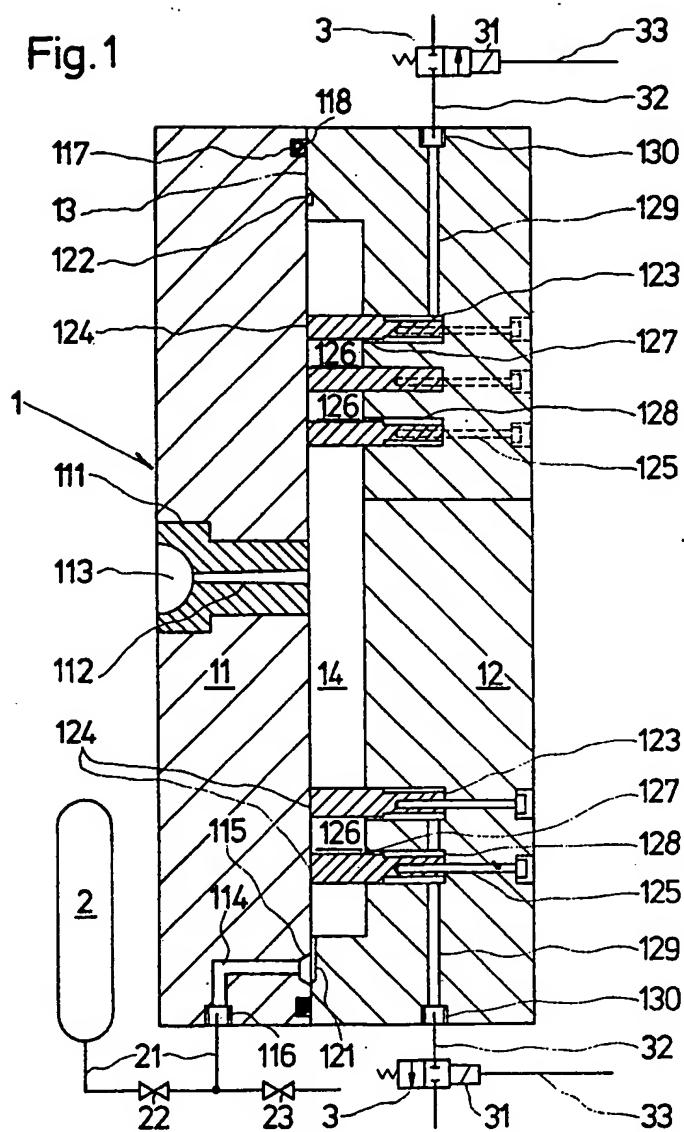


Fig. 2

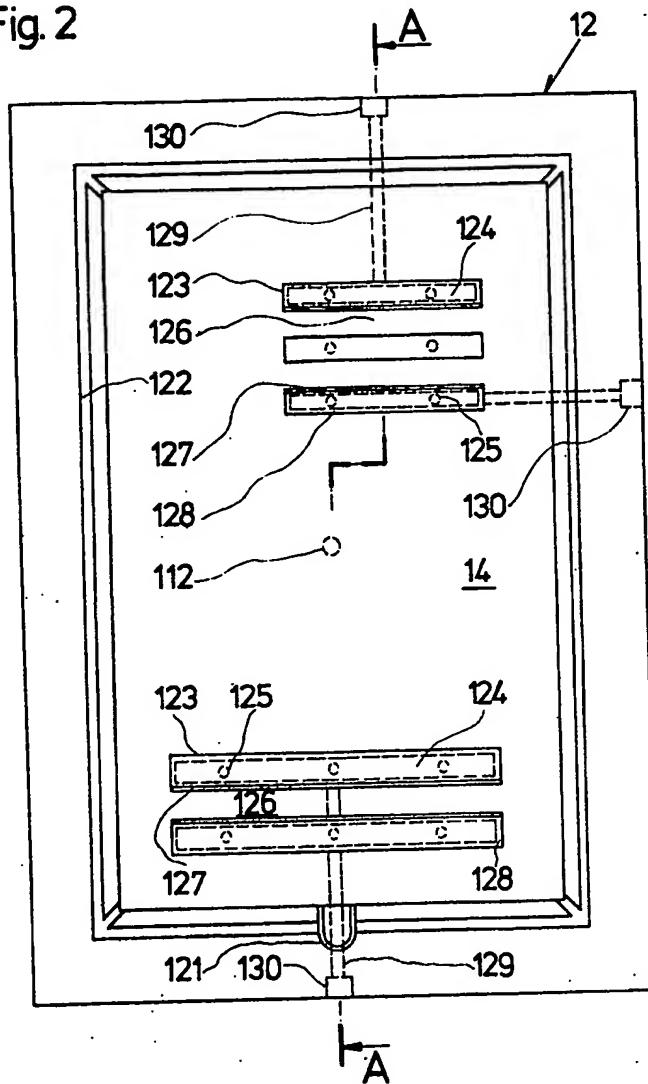
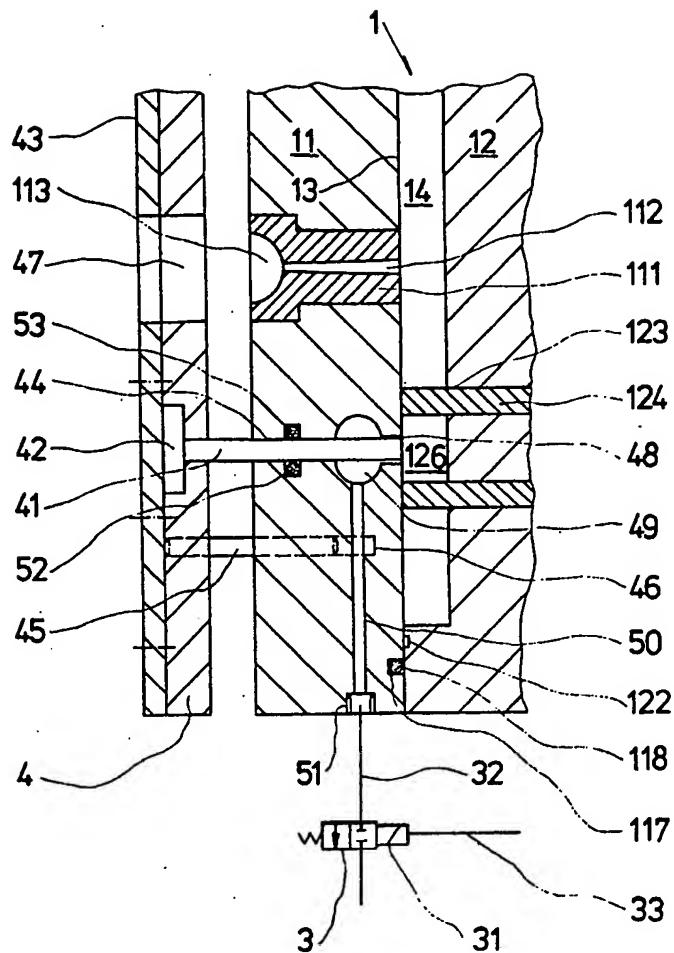


Fig. 3



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